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INDIAN STATE-LEVEL RICE PRODUCTIVITY AND ITS IMPACT ON POVERTY ALLEVIATION

BY

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This paper has a three fold contribution to the existing literature - 1) Indian state level sorghum input and output data for the period 1970-71 to 2000-01 is collected, 2) non-parametric and parametric productivity measures are estimated, and 3) examine the impact of percent acreage under high yielding varieties and irrigation, state domestic product, productivity and five year plans on poverty alleviation using error component and SUR models.

Keywords: India, Rice, Nonparametric and Parametric Productivity, Poverty, and Five year plans

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Technology led development in agriculture has made India self-sufficient in food grains and a leading producer of several agricultural commodities in the world. The Green revolution in foodgrain crops, Yellow revolution in oilseeds, White revolution in milk production, Blue revolution in fish production and Golden revolution in horticulture bear an ample testimony to the contributions of agriculture research and development efforts in the country. However the new crop technologies are mostly confined to specialized areas creating ecosystem imbalances. Further, differential factor use and resource endowment among ecosystems, season, and farm size has lead to skewed adoption of the new technology and productivity gains across Indian states.

Since post-independence India, coarse cereals followed by rice, pulses and wheat accounts for 34, 32, 19 and 16 percent respectively of the total acreage. However, rice takes the first spot in terms of production with 41 percent followed by 24 percent each by wheat and coarse cereals, and pulses with 11 percent of the total production of foodgrain and major non-foodgrain crops. Based on 2001-2002 production years, rice cultivation is found in all states, with West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Orissa., Tamil Nadu and Bihar constituting 73 percent of total production. Rice is grown through out the year under diverse production environments including kharif, mid-kharif and rabi seasons.

The introduction of first modern variety *Kalyansona* of wheat in 1967 and *Jaya* of rice in 1968 was the beginning of green revolution in India. Since then, about 2300 modern varieties of different food, fodder, fiber, and horticulture crops were released over the past 35 years of green revolution period. The access of modern varieties of rice and wheat backed by the favorable public policy support in the 60s and 70s induced farmers to invest more land, labor and capital resources for these crops-particularly in the irrigated environments. The green revolution induced growth in agriculture-especially in rice and wheat crops- over the past three decades had economy-wide effects that led to achieving food security and substantial reduction in poverty in India (Barker and Herdt, 1985; Pingali et al 1997). The incidence of poverty is lower in Indian states where there was higher adoption rate of modern varieties and irrigation coverage such as in Punjab, Haryana and Western parts of Uttar Pradesh (Janaiah, et al 2000). According to FAO, "rice-based production systems provide the main income and employment for more than 50 million households apart from being a staple food for 65% of the total population in India.".

Some recent studies indicated either a declining or stagnation in yield of the intensive irrigated rice systems (Cassman and Pingali, 1995; Pingali et al. 1997, Greenlands, 1997; Dawe et el. 2000). In most of these studies, the magnitude of yield decline was reported more for rice than for wheat-in fact a few studies reported increasing trend for wheat yields under irrigated ecosystem. Moreover, yield growth is not a true measure of technology impact, as it does not net out the effect of input growth from output growth. Thus, analyzing either total factor productivity (TFP), the residual of the ratio of output over vector of inputs would provide a more appropriate measure of the impact of technology in rice sector in India.

In the present study productivity measures are estimated for each of the ten rice producing states in India using inputs and output data, 1977-1996. The next section describes the nonparametric and parametric approaches in the estimation of productivity measures. The third section details the two-way random effects panel model to examine the impact of policy variables including the estimated productivity measures, percent acreage under high yielding varieties and irrigation, state gross domestic product, and most importantly the five-year plans. Fourth section present details and construction of the Indian state level rice inputs and output quantity data. The empirical application and results are presented in the fifth followed by conclusions in the final section.

Non-parametric and parametric productivity measures

Depending on the availability of the data, productivity measures can be estimated for a single firm using time series data (identified with technical change), multiple firms using cross-sectional data (identified with technical efficiency), and multiple firms over time using panel data (identified as a product of technical change and technical efficiency). To represent productivity, technical change or efficiency for a firm $i,\ i = 1, \ldots\ldots\ldots, I$ with time $t,\ t = 1, \ldots\ldots\ldots, T$, the basic form of the model in the primal approach can be represented as

(1) $y_{i,t} = f(x_{i,t}; \beta) \cdot \varepsilon_{i,t}$

where y denotes output produced from a vector of input, x and β the associated vector of parameters.

Equation (1) re-written as

$$(2) \qquad \varepsilon_{i,t} = \frac{y_{i,t}}{f(x_{i,t};\beta)}$$

represents the efficiency, technical change or productivity measures depending on the cross-section, time series and panel data. Equation (2) is utilized to estimate the individual state level efficiency measures by non-parametric or parametric approach using time series data as observations. Efficiency measures estimated in this fashion is equivalent to estimating productivity measures.

The past decade has witnessed a surge in the application of non-parametric techniques to productivity measurement, due to the ability to handle multiple outputs and inputs, imposes no structural functional form and compute efficiency and productivity measures without the need of prices. In general these methods are distance function approaches that compare the production plans that were available at time *T* with those that were available at time *t*. The productivity change over the interval is typically measured as the proportional increase in output that was achievable at *T* from year *T* inputs, relative to what would have been achievable at *t* from year *T* inputs. Implicit in the estimation procedure is estimation of the piece-wise linear convex production hull that envelops the set of production plans available at either point in time.

The particular non-parametric productivity measure considered here is the output productivity measures described in Shaik; or Färe, Grosskopf and Lovell, Chapter 4 section 1. In this approach, productivity gain between time t and time T is the proportion by which outputs could have been increased given inputs, in year T as compared to year t. To formally represent this measure, define the technology using the output reference set satisfying constant returns to scale and strong disposability of outputs:

(3) $P(x) = \{ y : x \text{ can produced } y \text{ in year } T ; \}$

A direct measure of productivity gain from year t to T can then be derived from the output distance function, or its equivalent programming problem

(4)
$$D^T(x^t, y^t)^{-1} = \max_{\theta, z} \{\theta : (x^t, \theta y^t) \in P^T(y^t)\}$$
$$or$$
$$\max_{\theta, z} \theta \quad s.t. \quad \theta y^t \leq Y z \qquad \text{where} \quad Y = (y^1, y^2, \ldots\ldots.., y^T)$$
$$x^t \geq X z \qquad X = (x^1, x^2, \ldots\ldots.., x^T)$$
$$z \geq 0$$

Thus, examining the year t production plan compared with the production possibilities revealed to be available through some future year T, a solution value of θ=1.2 would indicate that 20% more good outputs were observed in year t. Hence the interpretation is that the productivity increase between year t and year T was 20%.

Estimation of the above productivity measure includes estimation of the piecewise linear technology available at time T, with the estimated facets consisting of linear combinations of previously observed production plans. For a particular year t, the optimal values of z represent the linear combination of other years' plans that identify the frontier production facet to which the year t production point is projected (along a output arc identified by $(x^t, \theta y^t)$. In (2), z is a $\{Tx1\}$ vector of intensity variables with $z \geq 0$

identifying the constant returns to scale boundaries of the reference set. In (2), if z is equal to 1, then variable returns to scale boundaries of the reference set is identified.

Comprehensive literature reviews [Forsund, Lovell and Schmidt (1980), Schmidt (1986), Bauer (1990), Greene (1993), and Kumbhakar and Lovell (2000)] on the use of stochastic frontier analysis has been evolving since it was first proposed by Aigner, Lovell and Schmidt; Meeusen and van den Broeck; and Battese and Corra in the same year, 1977. The past five years has witnessed an outpouring of the parametric techniques to estimate efficiency and productivity measures. Furthermore within the primal framework progress has been made on the ability to handle multiple outputs and inputs via the distance functions, adjusting for time series properties, incorporating autocorrelation and heteroskedasticity, and finally the use of Bayesian techniques in the parametric efficiency measures.

To be consistent with the above non-parametric procedure, the productivity measures are estimated individually using panel data. The particular parametric productivity measure considered here is the productivity measures equivalent to efficiency measures estimation from a primal production function. In this approach, productivity gain between time t and time T is the proportion of efficiency by which outputs could have been increased given inputs, in year T as compared to year t. To formally represent this measure, equation (1) can be re-written to represent the parametric stochastic frontier analysis model that includes decomposed error as:

(5) $y = f(x;\beta)\cdot v - u$

where v representing firm or time specific random error which are assumed to be iid and normally distributed variable with mean zero and variance σ_V^2; u representing the technical efficiency which must be positive hence absolutely normally distributed variable with mean zero and variance σ_U^2; and y, x and β as defined in equation (1).

Equation (1) re-written as

$$(6) \qquad u = \frac{y}{f(x_{i,t};\beta)\cdot v}$$

represents the non-parametric productivity measures.

With the paper by Jondrow, Lovell, Materov, and Schmidt in 1982, individual firm or time specific u conditional on ε can be represented as

$$(7) \qquad E(u\,|\,\varepsilon) = \frac{\sqrt{\sigma_V^2+\sigma_U^2}\,\dfrac{\sigma_U^2}{\sigma_V^2}}{1+\left(\dfrac{\sigma_U^2}{\sigma_V^2}\right)^2}\left[\frac{\phi(a_{it})}{1-\Phi(a_{it})}-a_{it}\right]$$

where $a = \varepsilon\dfrac{\sqrt{\sigma_V^2+\sigma_U^2}}{\sigma_U^2/\sigma_V^2}$, and ϕ and Φ are the standard normal density and standard normal cumulative density function.

Impact of rice productivity on poverty alleviation

Individual state level rice input and output data are used to estimate rice productivity measures for ten rice growing states in India. Next, we examine the impact of policy variables on poverty alleviation using the two-way error component model.

Consider an error component model with the additive error ε differentiated into temporal component, u, spatial component, v and remaining residual component, w as:

$$y = x\beta + u + v + w \tag{8}$$

where y is the poverty alleviation variable and x are the vector of exogenous policy variables including percentage of area under high yielding varieties, irrigated acreage, overall state net state domestic product, five year plans and the estimated rice productivity measures.

The errors of a two-way random effects model can be represented as

$$\begin{aligned} u' &= \left(u_1', u_2', ..., u_N'\right), \quad N = \text{cross sectional units} \\ v' &= \left(v_1', v_2', ..., v_T'\right), \quad T = \text{time series} \\ w' &= \left(w_1', w_2', ..., w_{NT}'\right) \end{aligned} \tag{9}$$

are random vectors with zero means and covariance matrix

$$E\begin{pmatrix} u \\ v \\ w \end{pmatrix}\left(u\, v\, w\right) = \begin{pmatrix} \sigma_u^2 I_N & 0 & 0 \\ 0 & \sigma_v^2 I_T & 0 \\ 0 & 0 & \sigma_w^2 I_{NT} \end{pmatrix} \tag{10}$$

Equation (11) can be alternatively represented as

$$\begin{aligned} E\left(\varepsilon\, \varepsilon'\right) &= \Omega \\ &= \sigma_w^2\left(\iota_N \otimes \iota_T\right) + \sigma_u^2\left(I_N \otimes \iota_T\right) + \sigma_v^2\left(I_T \otimes \iota_N\right) \end{aligned} \tag{11}$$

Indian State-wise Output and Input Data

Indian state level rice data span a period of 31 years from 1970-71 to 2000-01. Estimated aggregate output and five input Tornqvist-Theil quantity indices for eight sorghum producing states in Indian are used in the analysis. The states include, Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Madhya Pradesh, Orissa, Punjab, Tamilnadu, Uttar Pradesh and West Bengal.

In contrast with earlier productivity measures, this study uses the cost of cultivation rice data on per hectare basis by state in the estimation. Input-output data from the reports of a comprehensive scheme *Cost of Cultivation of Principal Crops in India*, Ministry of Agriculture, Government of India were compiled, and used for measurement and analysis of state level productivity. Under cost of cultivation scheme (CCS), farm-level data from the selected sample were collected by cost-accounting method every crop year since 1970 for all major crops in major states. However, sample size varies from state to state, crop to crop, and year to year. The principal purpose of collecting farm level input and output data under CCS is estimate cost of production for principal crops, which is a basis for the Government of India to fix procurement price at which farmers sell their produce to the government buffer stocks. The summary (state level averages) of key variables of this data such as all inputs and output will be published every year with 3-4 years lag. The time series data on quantities and values of inputs were collected from all available reports of CCS for rice for the period 1970-71 to

1999-2000 for all major states of India. We used this data set for measurement of state-level productivity.

Quantity data was available for input and output, however the fixed cost available in rupees per hectare are converted into implicit quantity index using gross domestic product implicit price deflator. To overcome the gaps and not availability of the complete dataset, the time series was reduced to 20 years for the period, 1977-1996. The inputs include seed, fertilizer, manures, animal labor, human labor and capital.

Additionally poverty measures[1] – head count index, poverty gap index and squared poverty gap index; percent of acreage under high yielding varieties and irrigation; net state domestic product at 1993 constant prices; and five year plans) are collected and constructed from various sources including FAO, World Bank, Central Statistical Office, Delhi and individual State Directorate of Economics and Statistics. Table 1 presents the summary statistics of the input and output used in the estimation of productivity measures. Also present in Table 1 are the summary statistics of the estimated productivity measures, poverty measures and policy variables used in the regressions.

[1] Definition and computation of the three measures of poverty are detailed on the Planning Commission of India or the World Bank webpage.

Empirical Application and Results

To examine the impacts of policy variables including productivity on poverty alleviation, non-parametric and parametric productivity measures are estimated based on equation (4) and (5) respectively. Figure 1 presents the parametric[2] productivity measures of the ten major rice producing states in India. Further the four moments, mean, standard deviation, skewness and kurtosis measures are presented in Table 1.

Equation (8) is estimated to examine the impact of policy variables like percent of acreage under high yielding varieties and irrigation; net state domestic product at 1993 constant prices; five year plans; including productivity measures on poverty alleviation. To account for the spatial and temporal variation in the regressions, the specified equation (8) is a two-way random effects panel model. This model is estimated for the three variations of the rural poverty measures - – head count index, poverty gap index and squared poverty gap index. Regression results are presented in Table 2. As the variables used in the regression results are in logs the parameter coefficient can be interpreted as elasticity. As expected, the estimated productivity measures, percent acreage under high yielding varieties (HYV) and real net state domestic product had an inverse relationship with poverty measures. Simple said, an increase in the above variables lead to a decrease in the poverty. Positive relationship between poverty and percent acreage under irrigation; and the five year plans indicates an increase in the poverty. However the recent five year plan periods seems to have a decreasing impact on poverty alleviation.

[2] Non-parametric measures have also been estimated by not presented due to space limitations.

Alternatively, seemingly unrelated regression (SUR) equation estimation is performed with rural and urban poverty indexes forming the endogenous variables and the estimated productivity measures; percent acreage under high yielding varieties and irrigation; real net state domestic product; and five year plans the exogenous variables. In this model, the five year plans seems to be inversely and directly related to urban and rural poverty measures respectively.

Conclusions and Implications

This paper examines the importance of productivity and policy variables on poverty alleviation in India using state level data for the period, 1977-1996. State level estimated productivity measures indicate an increase over the time period. Further the importance of productivity measures, percent acreage under high yielding varieties (HYV) and real net state domestic product on poverty alleviation is reflected in the two-way random effects panel model regression results. However, the five year plan periods does seem to portray an inverse relationship with poverty measures. Alternative SUR regression results seem to indicate an inverse relationship of five year plans to urban and not rural poverty.

Further, work in the area of estimating the state level agricultural total factor productivity or estimate state and crop wise total factor productivity needs to be flushed. On the poverty measures, fine tuning by incorporating the quality aspects is needed.

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Figure 1. India State-wise Rice Total factor productivity measures, 1977-1996

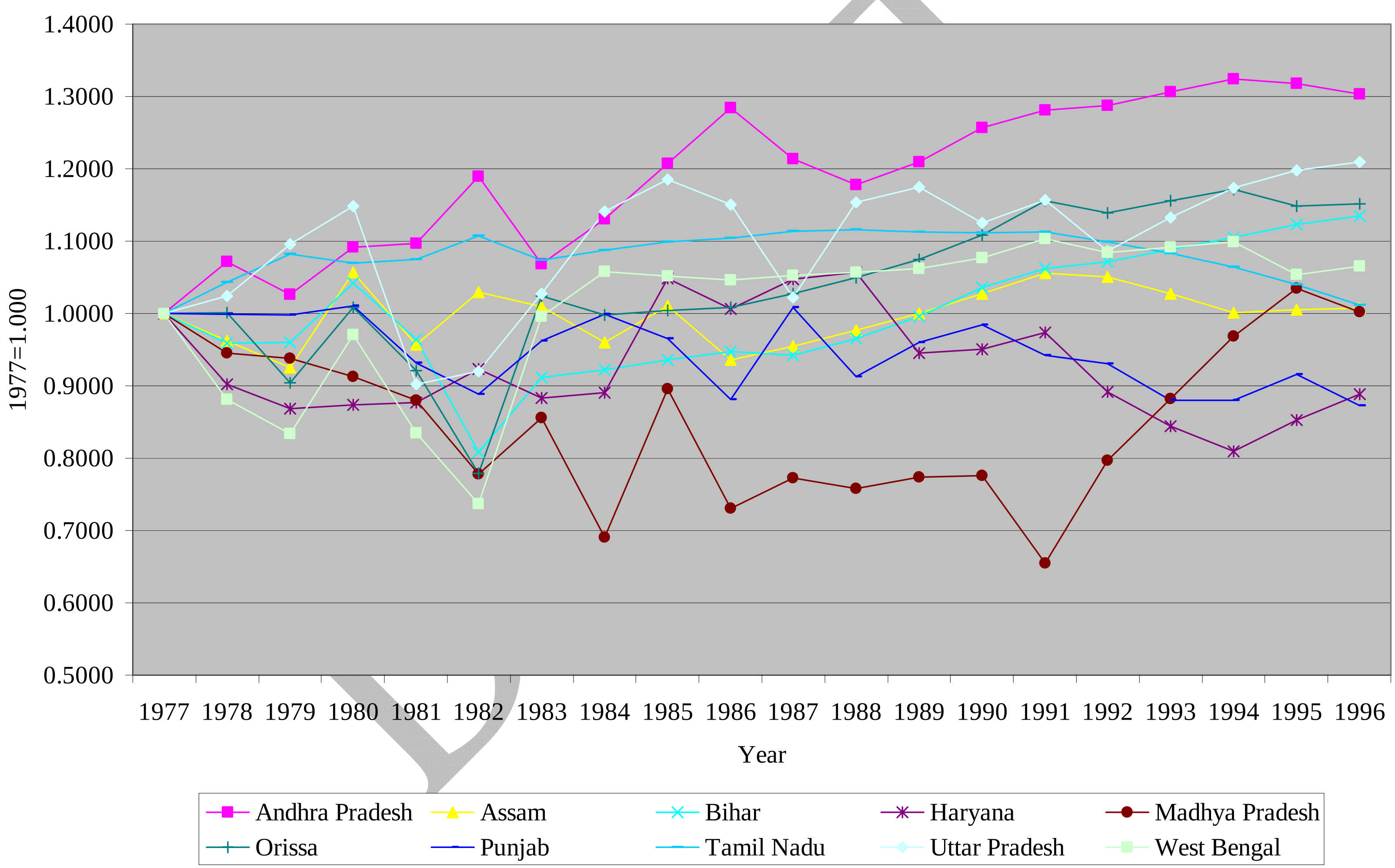

Table 1. Summary Statistics of Variables used in the Analysis, 1977-1996

	Units	Minimum	Maximum	Mean	Std.Dev.	Skewness	Kurtosis
Productivity Equation Variables							
Yield	Quintals/ha	11.2400	58.9700	28.7187	11.4222	0.7700	-0.3118
Seed	Kgs/ha	4.6873	100.7300	58.4820	30.2591	-0.5030	-1.1090
Fertilizer	Kgs-Nutrients/ha	0.0200	216.3000	82.4507	62.4167	0.4693	-1.0868
Manure	Quintals/ha	0.3200	86.4400	22.0946	18.8827	1.2713	1.3825
Animal Labor	000's Man hours/	0.0010	0.2945	0.1478	0.0859	-0.1031	-1.1485
Human Labor	000's Paid hours/	0.4443	1.3276	0.8756	0.2225	0.1685	-1.0605
Capital	Implicit quantity index	0.1255	1.3281	0.6080	0.2941	0.6822	-0.6322
Poverty Equation Variables							
Head count- Urban	Percentages	6.5513	59.7500	35.9652	13.1704	-0.3040	-0.7064
Poverty gap - Urban	Percentages	0.2144	23.6490	9.5801	4.8154	0.2168	-0.2558
Square poverty gap - Urban	Percentages	0.0093	11.8190	3.5878	2.2361	0.7680	0.8892
Head count- Rural	Percentages	11.0523	69.9400	42.8212	14.5345	-0.1968	-0.8726
Poverty gap - Rural	Percentages	1.5295	22.4770	11.1891	5.2805	0.2568	-0.8167
Square poverty gap - Rural	Percentages	0.2979	9.5350	4.1441	2.4328	0.5436	-0.6895
Productivity Measures	Numbers	0.5640	0.9906	0.8543	0.0914	-0.8326	0.1585
Percent acreage under HYV	Percentages	0.1469	1.2054	0.6357	0.2543	0.0277	-1.1563
Percent acreage under Irrigation	Percentages	0.0922	1.0258	0.5588	0.3371	0.2859	-1.7838
Real State Domestic Product	1993 constant Rs. Crores	7424	85563	27406	16382	1.1723	0.8734
Fifth five year plan (1977 - 1980) = 1		0	1	0.1500	0.3580	1.9752	1.9207
Sixth five year plan (1980 - 1985) = 1		0	1	0.2500	0.4341	1.1634	-0.6530
Seventh five year plan (1985 - 1990) = 1		0	1	0.2500	0.4341	1.1634	-0.6530
Annual year plans (1990 - 1992) = 1		0	1	0.1000	0.3008	2.6869	5.2718
Eight five year plan (1992 - 1997) = 1		0	1	0.2500	0.4341	1.1634	-0.6530

Table 2. Regression Results of Two-way Random Effects Model

	Estimate	StdErr	tValue	Probt
Head count ratio equation				
Productivity Measures	-0.2250	0.1075	-2.0929	0.0377
Percent acreage under HYV	-0.1100	0.0378	-2.9076	0.0041
Percent acreage under Irrigation	0.1524	0.0584	2.6105	0.0098
Real State Domestic Product	-0.3434	0.0859	-3.9998	0.0001
Fifth five year plan (1977 - 1980) = 1	7.2170	0.8405	8.5866	0.0000
Sixth five year plan (1980 - 1985) = 1	7.1960	0.8530	8.4362	0.0000
Seventh five year plan (1985 - 1990) = 1	7.1294	0.8725	8.1709	0.0000
Annual year plans (1990 - 1992) = 1	7.0535	0.8876	7.9469	0.0000
Eight five year plan (1992 - 1997) = 1	7.1725	0.8982	7.9851	0.0000
Poverty gap equation				
Productivity Measures	-0.3608	0.1716	-2.1026	0.0368
Percent acreage under HYV	-0.2081	0.0604	-3.4454	0.0007
Percent acreage under Irrigation	0.2423	0.0917	2.6425	0.0089
Real State Domestic Product	-0.4533	0.1312	-3.4542	0.0007
Fifth five year plan (1977 - 1980) = 1	6.9754	1.2843	5.4312	0.0000
Sixth five year plan (1980 - 1985) = 1	6.9413	1.3032	5.3263	0.0000
Seventh five year plan (1985 - 1990) = 1	6.8080	1.3330	5.1073	0.0000
Annual year plans (1990 - 1992) = 1	6.6532	1.3559	4.9069	0.0000
Eight five year plan (1992 - 1997) = 1	6.8209	1.3721	4.9712	0.0000
Squared poverty gap equation				
Productivity Measures	-0.4991	0.2343	-2.1303	0.0344
Percent acreage under HYV	-0.2927	0.0824	-3.5518	0.0005
Percent acreage under Irrigation	0.3248	0.1229	2.6424	0.0089
Real State Domestic Product	-0.4798	0.1772	-2.7075	0.0074
Fifth five year plan (1977 - 1980) = 1	6.2502	1.7324	3.6079	0.0004
Sixth five year plan (1980 - 1985) = 1	6.1989	1.7579	3.5262	0.0005
Seventh five year plan (1985 - 1990) = 1	5.9861	1.7982	3.3289	0.0010
Annual year plans (1990 - 1992) = 1	5.7375	1.8293	3.1364	0.0020
Eight five year plan (1992 - 1997) = 1	5.9673	1.8511	3.2236	0.0015

Table 3. Regression results of iterative seemingly unrelated regression model

	Estimate	StdErr	tValue	Probt
<u>Urban Head count ratio equation</u>				
Productivity Measures	-0.8583	0.2573	-3.3357	0.0010
Percent acreage under HYV	-0.1582	0.1061	-1.4914	0.1375
Percent acreage under Irrigation	-0.0633	0.0613	-1.0327	0.3031
Real State Domestic Product	0.3437	0.0540	6.3602	0.0000
Fifth five year plan (1977 - 1980) = 1	0.1060	0.5532	0.1917	0.8482
Sixth five year plan (1980 - 1985) = 1	-0.0420	0.5489	-0.0765	0.9391
Seventh five year plan (1985 - 1990) = 1	-0.2245	0.5558	-0.4039	0.6868
Annual year plans (1990 - 1992) = 1	-0.4458	0.5657	-0.7881	0.4316
Eight five year plan (1992 - 1997) = 1	-0.5782	0.5657	-1.0222	0.3080
<u>Rural Head count ratio equation</u>				
Productivity Measures	-0.7679	0.2016	-3.8079	0.0002
Percent acreage under HYV	-0.2742	0.0831	-3.2983	0.0012
Percent acreage under Irrigation	-0.1803	0.0481	-3.7525	0.0002
Real State Domestic Product	0.1284	0.0424	3.0310	0.0028
Fifth five year plan (1977 - 1980) = 1	2.1070	0.4335	4.8604	0.0000
Sixth five year plan (1980 - 1985) = 1	2.0514	0.4302	4.7691	0.0000
Seventh five year plan (1985 - 1990) = 1	1.9484	0.4356	4.4728	0.0000
Annual year plans (1990 - 1992) = 1	1.8227	0.4433	4.1114	0.0001
Eight five year plan (1992 - 1997) = 1	1.9223	0.4433	4.3365	0.0000